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Waste flow mapping to improve sustainability of waste management: a case study approach

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ABSTRACT

Innovative, resource-efficient solutions and effective waste management systems capture value in business and contribute to sustainability. However, due to scattered waste management responsibilities in the vehicle industry and the orientation of operations management and lean tools, which mostly focus on lead-time and labour-time improvements, the requirement of a collaborative method to include material waste efficiency in operational development is identified. The main purpose of this research is to study how operations management and environmental management can be integrated on an operational level and include the waste management supply chain. Based on a literature review of environmental and operational improvement tools and principles, the gaps and needs in current practice were identified. A large case study implementing a waste flow mapping (WFM) method on a set of manufacturing sites revealed potentials in terms of reducing material losses and inefficiencies in the handling of materials and waste. Finally, the integrated WFM method was analysed with respect to the gaps and needs identified in the existing body of tools for operational and environmental improvement. The method combines lean manufacturing tools, such as value stream mapping with cleaner production and material flow cost accounting strategies. The empirical data showed that the WFM method is adequate for current state analysis of waste material efficiency potentials, especially when multiple organisations are involved. However, further development and specific methods are needed such as, for example, logistics inefficiencies, root cause analysis, implementation guidelines for best practice and systems for performance monitoring of actors.

1. Introduction

1.1. Background

In manufacturing there are several production steps where sustainability (UN, 1987) has increasingly come into focus in terms of less use of resources including energy, chemicals and water, and lower generation of waste and emissions to air and water. With increasing demands on material and upcoming shortages of resources, material efficiency is becoming increasingly important for the operational strategies of manufacturing companies (Allwood et al., 2011). To meet the challenges of sustainability, environmental management standards such as ISO 14001 have supported companies focussing on environmental performance improvements, especially regarding material waste (Zackrisson et al., 2000); in addition, various sustainable management norms, visions and directions such as natural capitalism, ecological step, and Factor 10 have been introduced by various authors. The World Economic Forum (2012) still identifies innovative resource-efficient solutions and business models as the most strategic option to capture value in industry.

Today lean manufacturing is the paradigm in industrial management in the automotive industry. It focuses on elimination of work losses, particularly any human activity that absorbs resources but creates no value. The principles and tools of lean manufacturing

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have proven fruitful in engaging all employees in improvement activities. Still, only few structured practical tools have been developed for both production managers and environmental engineers (Torres and Gati, 2009). For instance, value stream mapping (VSM) is a common tool in lean manufacturing used by production engineers, while energy and material surveys are used in environmental management by environmental engineers (Bergmiller and McCright, 2009). As a consequence, to minimise the environmental impact from production, earlier studies (EPA, 2003; Florida, 1996; Herrmann et al., 2008; King and Lenox, 2001) have identified lean and green as a preferred approach to realising environmental opportunities. The overall aim of lean and green approaches is to include environmental principles in the lean principles and then derive appropriate tools for the challenges. In integrating environmental and lean approaches, it is not only essential to analyse the input–output flow of energy and materials but also to visualise the current state and the improvement potentials to involve all people (Bergmiller and McCright, 2009; Höckerdal, 2012).

This paper focuses on the waste management part of operations management. The importance of the end-of-life phase from an environmental point of view has been shown in several studies (Lundqvist et al., 2004; Zackrisson et al., 2000), and the economic potential of improving material efficiency by climbing the waste hierarchy has been demonstrated (e.g., Tang and Yeoh, 2008). Even effective and environmentally aware companies have opportunities to improve waste management (Halme et al., 2007), mostly because waste management often involves several actors and staff from various organisations, making it difficult to manage. A specific character of waste management improvement tools is thus to support waste management service supplier development. A major driver of environmental improvements in supply chains is the demands imposed by customers on suppliers (Nawrocka et al., 2009), which are dependent on information sharing, mutual understanding and agreement and trust (Simpson and Power, 2005).

1.2. Scope and research questions

Based on the lack of tools for combined operations and environmental improvement, the complexity in waste management improvement and the scarcity of larger case studies on lean and green improvement implementations, a case-based study on sustainability improvement and realisation of waste management values was designed. This study focuses on an analysis of the material waste management supply chain, especially on the interface between waste management and production management because this interface is crucial to the rest of the waste management process.

The objective of the study was to enhance the knowledge of how operations management and environmental management can be integrated on an operational level, focussing on the waste management supply chain. To fulfil this objective, the following research questions were identified:

1. What are the characteristics and gaps in existing operational improvement and environmental improvement tools and principles?
2. What potential in terms of material losses and inefficiencies in the handling of materials and waste can an integrated waste flow mapping method reveal while implemented in a broader empirical study?
3. How can the integrated waste flow mapping method answer to the gaps and needs identified in (1) by analysing the existing body of tools for operational and environmental improvement?

To answer these questions, the remainder of the paper is organised as follows: Section 2 presents the frame of reference describing existing tools and principles for operational improvement and environmental improvement, concluding with the identified gaps and criteria of an integrated lean and green improvement method. Section 3 introduces the material and methods for the empirical data collection and analysis. Section 4 briefly presents the integrated waste flow mapping method applied to the set of manufacturing sites. The method was intended to find economically competitive environmental improvements on the team, site and multi-site levels through best practice examples and to define suitable performance indicators to secure implementation and continuous improvements. Section 5 presents the direct quantitative results from the broad case study where the method was applied to indicate potential in terms of material losses and inefficiencies in the handling of materials and waste. Finally, Section 6 discusses the qualitative methodological character of applying a method integrating operational and environmental improvement on this large set of manufacturing sites. This methodological analysis and discussion identifies potentials and existing gaps in the method, in contrast to the requirements in Section 2.

2. Frame of reference: tools and principles employed for lean manufacturing and environmental analysis

Since the 1990s, operations management research and practice has had a strong focus on lean manufacturing (Jayaram et al., 2010; Rother, 2010). The focus has shifted from utilisation of equipment and labour to reducing lead time and non-value-adding work (Modig and Åhlström, 2012). Since then it has been debated whether lean is also green (Dües et al., 2013), and in many respects the benefits of lean production for cleaner production have been emphasised (Bergmiller and McCright, 2009), especially in reducing non-value-adding processes and energy. However, there is still a large untapped potential in increasing energy and material efficiency and reducing losses in wasted material (Allwood et al., 2011; World Economic Forum, 2012).

There exists a multitude of methods and tools for environmental management purposes (Lindahl, 2005) such as cleaner production approaches (Lebersorger, 2008) and material flow cost accounting (Allen et al., 2009; Jasch, 2003), although these are not prescribed in the ISO 14000 standards and thus different companies use different tools. Regarding lean production, the principles and tools are more uniform, but different interpretations of how to use them for environmental challenges exist (Zokaei et al., 2013). This section briefly introduces existing principles and tools used for operations management (lean manufacturing) and environmental analysis in an operational improvement context. The section concludes by specifying the requirements placed on an integrated method for operational and environmental improvement focussing on the material waste management supply chain.

2.1. General lean principles and tools. Continuous reduction of losses or “lean waste”

Lean production focuses on reducing “Muda”, which is interpreted as “losses”, “waste”, “waste of time” (rather than material waste) (Hillenbrand, 2002) or “non-value-adding activities” (Zokaei et al., 2013). A key issue in lean philosophy is involving all staff in continuous improvement, where a number of tools and techniques are used. Successful continuous improvement (CI) demands that mutual trust exists between the people involved in operations and that people are empowered to implement improvements (Berglund et al., 2011; Moxen and Strachan, 1998). This trust will depend on transparent information, which becomes even

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